

Appendix A. Study Design for the Lower Yakima River, 2005–07

Table A1. Study approach for the lower Yakima River, Washington, 2005–07.

Study element	Question	Data collection	Data analysis
Macrophyte abundance	What were the differences between macrophyte biomass in the three reaches?	Measured macrophyte biomass in the Zillah, Mabion, and Kiona reaches in late summer of 2005.	Compared median values between reaches.
	What were the differences in macrophyte biomass between years?	Measured macrophyte biomass in the Kiona reach in late summer of 2005, 2006, and 2007.	Compared median values between years.
Periphyton abundance	What was the periphyton biomass in the Zillah reach?	Measured periphyton biomass in a 16-mile portion of the Zillah reach in 2005 (June), 2006 (July, September, October) and 2007 (June, July, August, September).	Not applicable.
Relations between aquatic plant abundance and nutrients	What were the differences in periphyton biomass between years?	No additional data collection was performed.	Compared median values for the Zillah reach for 2006 and 2007
	Was periphyton biomass different in reaches with different nutrient concentrations?	In July and August 2007, measured periphyton biomass at one to two sites in the Naches River (low nutrients) and two to three sites in the Zillah reach (moderate nutrients).	Compared median values between reaches.
	Were nutrient concentrations limiting periphyton growth in the Zillah reach?	Measured periphyton biomass and surface water nutrient concentrations in a 16-mile portion of the Zillah reach in 2005 (June), 2006 (July, September, October) and 2007 (June, July, August, September).	Compared periphyton biomass to nutrient concentrations, and compared nutrient concentrations and algal biomass to suggested U.S. Environmental Protection Agency reference concentrations.
	Did periphyton productivity increase between reaches with increasing nutrient concentrations?	Measured periphyton productivity in response to nutrient treatments in a 16-mile portion of the Zillah reach using periphytometers at four sites in August and October of 2006 and at two to three sites in July and September of 2007.	Used analysis of variance to evaluate periphyton accrual rates in response to nutrient treatments.
	Was hyporheic flow providing nutrients to periphyton in the Zillah reach?	In July 2007, measured periphyton accrual rates using periphytometers at two sites in the Naches River (low nutrients), three sites in the Zillah reach (moderate nutrients), and one site in the Kiona reach (high nutrients).	Used analysis of variance to evaluate periphyton accrual rates in response to nutrient treatments.
	Was hyporheic flow providing nutrients to periphyton in the Zillah reach?	Obtained paired samples of surface water and porewater and vertical hydraulic gradients in the Zillah reach in June 2005 at one site (to assess the feasibility of the sampling technique), in July 2006 at nine sites, and in July 2007 at three sites.	Compared results between sites.

Table A1. Study approach for the lower Yakima River, Washington 2005–07.—Continued

Study element	Question	Data collection	Data analysis
Relations between aquatic plant abundance and nutrients—Continued	Were nutrients from the water column taken up by algae or macrophytes?	(1) Sampled nutrients at the upper and lower boundary of 1.5–2-mile sections within the Zillah, Mabton, and Kiona reaches in July and August 2005. (2) Measured surface water nutrient concentrations at RM103 and RM87 in the Zillah reach in 2006 (July, September, October) and 2007 (June, July, August, September).	(1) Compared differences in nutrient concentrations between upper and lower boundaries of the three reaches in 2005. (2) Determined if the declines in nutrient concentrations in the Zillah reach in 2006 and 2007 followed the Redfield ratio.
	Could differences in nutrient concentrations account for the differences between reaches in macrophyte biomass? (1) Were macrophytes nutrient-limited in the Zillah and Kiona reaches? (2) Did differences in macrophyte abundance between reaches match reach-scale differences in nutrient concentrations in (a) surface water or (b) bed sediment?	(1) Collected 12 macrophyte tissue samples from the Zillah reach (4 samples on September 2, 2005) and the Kiona reach (8 samples on August 30, 2005) and analyzed samples for total nitrogen, total phosphorus, and total carbon content. (2a) No additional data collection was performed. (2b) Searched existing literature for nutrient concentrations in Yakima River bed sediment.	(1) Determined if nutrient concentrations in plant tissues were above or below established critical concentrations. (2a) Compared median macrophyte biomass in late August 2005 from a 1.5–2-mile portion of each reach to nutrient concentrations measured in June, July, and August, 2005 in each reach. (2b) Compared average concentrations of nutrients in the sediment by reach to critical concentrations
Relations between aquatic plant abundance and physical parameters	Did periphyton biomass within the Zillah reach relate to water depth and velocity?	Measured periphyton biomass and water depth and velocity in a 1.6-mile portion of the Zillah reach in 2005 (June), 2006 (July, September, October) and 2007 (June, July, August, September).	Used linear regression to determine the relation between periphyton biomass and water depth and velocity.

Table A1. Study approach for the lower Yakima River, Washington 2005–07.—Continued

Study element	Question	Data collection	Data analysis
Relations between aquatic plant abundance and physical parameters—Continued	Could 15-minute increment turbidity data be used to indicate the duration of light-limiting conditions?	No additional data collection was performed.	Used linear regression to determine the relation between Zc and turbidity values.
	Did differences in macrophyte abundance between years at Kiona relate to differences in light availability?	Obtained rating-curve shifts for Kiona gage (RM 30) between 1996 and 2004, and snowpack data for east slope of the Cascade Range.	Used rating-curve shifts as an indirect measurement of relative macrophyte abundance at Kiona prior to the study. Compared indirect measurements of macrophyte abundance (1996–2004) and measured macrophyte biomass (late summer 2005, 2006, 2007) to factors influencing light abundance (continuous data for streamflow for all years, discrete turbidity measurements for 1996–2003, continuous turbidity data for 2004–07, and Zc values for 2005–07). Compared streamflow between 1996 and 2007 to period-of-record averages. Calculated number of days with above-average streamflow at Kiona, March–June 1996 to 2007. Analyzed snowpack data by calculating the percent of average snowpack (March–April, 1997–2007).
	Did macrophyte biomass within the Kiona reach relate to water depth and velocity?	Measured paired water depths and macrophyte biomass at 30 sites in a 2-mile section of the Kiona reach in 2005. Measured water velocity, water depth, and biomass at the same 30 sites in 2006 and 2007.	Used linear regression to determine the relation between macrophyte biomass and water depth and velocity.
Relations between dissolved oxygen and pH conditions and aquatic plant abundance	Were the patterns in dissolved oxygen and pH conditions between reaches and between years explained by differences in macrophyte and periphyton abundance?	No additional data collection was performed.	Compared the mean daily minimum dissolved oxygen and daily maximum pH from July 1 to August 31 in the Zillah reach (2005–06), Mabion reach (2005), and Kiona reach (2004–07) using Tukey's test for overlapping confidence intervals.

Table A1. Study approach for the lower Yakima River, Washington 2005–07.—Continued

Study element	Question	Data collection	Data analysis
Relations between dissolved oxygen and pH conditions and physical parameters	Did dissolved oxygen and pH conditions relate to water temperature, streamflow, or turbidity	No additional data collection was performed.	Used linear regression to determine the relation between daily minimum dissolved oxygen concentration and pH and the daily maximum water temperature, daily average streamflow, and daily median turbidity during March–September at Kiona (2004–07), Mabton (2005), and Zillah (2005–06). Developed a linear model for Kiona and compared the fitted and actual daily minimum dissolved oxygen concentrations for 2004–07 for March–September.
How did diel swings in dissolved oxygen and pH vary between seasons and between years with different streamflow patterns?	No additional data collection was performed.	Compared diel swings in dissolved oxygen concentrations and pH between spring (March–June) and summer (July–September) and between years at Kiona (2004–07), Mabton (2005), and Zillah (2005–06).	
Spatial variability in water-quality	Was there longitudinal variation in primary productivity, water temperature, dissolved oxygen, and pH conditions within the Zillah reach?	Measured water temperature, dissolved oxygen, pH continuously during periphytometer deployments at three sites (upper boundary, midway, and lower boundary) in a 16-mile portion of the Zillah reach during 2006 and 2007.	Compared the range in dissolved oxygen concentrations and pH (as indicators of primary productivity), calculated the percentage of readings above the State standards for dissolved oxygen concentration, water temperature, and pH, and compared the severity of dissolved oxygen and pH conditions to water temperature conditions.
Gross primary productivity	Can estimates of gross primary productivity (GPP) based on the diurnal oxygen curve method be used to estimate aquatic plant abundance in lieu of direct biomass measurements?	For two-station productivity estimates: measured dissolved oxygen and water temperature at the upstream and downstream edges of a 1.5-mile section in the Zillah reach during July–September, 2005 and a 2-mile section of the Kiona reach during July–October 2005 and during July and August 2007. Measured water velocity and depth within each reach to obtain reach averaged values needed for to estimate the re-aeration coefficients.	Compared one-station to two-station GPP results at Zillah and Kiona in 2005 and 2007. Compared summer GPP estimates from 2005–07 to macrophyte biomass measured in the Kiona reach.
	What were the important factors related to GPP?	No additional data collection was performed.	Used linear regressions to determine the relation between springtime GPP at Kiona, March–June, 2005–07 and five factors (daily average streamflow, daily average turbidity, photoperiod, daily average PAR, and daily maximum water temperature). Only springtime data were evaluated because the GPP estimates during summertime did not appear to be reliable indicators of relative plant abundance.